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REPORT OF TEST

PROJECT NR AVN 1860

6 S-60 CRANE

CONCEPT EVALUATION,

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UNITED STATES ARMY AVIATION BOARD

FORT RUCKER, ALABAMA

PROJECT NR AVN 1860

S–60 CRANE CONCEPT EVALUATION

I. PURPOSE

To conduct an evaluation of the S-60 crane helicopter to determine if the state-of-the-art improvements which exist in this helicopter warrant consideration for future Army crane helicopters.

II. SCOPE

The Sikorsky S-60 Crane Helicopter was flown by aviators of the United States Army Aviation Board for a total of ten flight hours in the vicinity of Fort Rucker, Alabama. In addition, a Board pilot assisted in the evaluation at Fort Benning and Fort Bragg for an additional seven hours. The evaluation was limited in flying hours by the short time that this helicopter was available. Emphasis was placed upon the helicopter crane concept and features which indicate new developments in the state of the art, for future Army use.

III. GENERAL INFORMATION

1. Background. Sikorsky Aircraft placed the S-60 Crane Helicopter under contract to the Army for an evaluation of the crane helicopter concept. This aircraft was flown from Stratford, Connecticut, and arrived at Fort Rucker, Alabama, 16 August 1959. The S-60 was made available to the United States Army Aviation Board for ten hours of flight time.

2. Description of Materiel. The Sikorsky S-60 is a crane-type helicopter powered by two Pratt and Whitney R-2800 reciprocating engines and incorporates many of the proven major components of the Sikorsky H-37 helicopter. The S-60 was equipped with Automatic Stabilization Equipment (ASE) and a hover coupler. This aircraft was built around a proven rotor system and engines by Sikorsky Aircraft, to demonstrate and develop the crane helicopter concept. To combine the helicopter ability with the optimum load carrying methods, the S-60 employs a completely new functional design, a Flying Crane, with a unique configuration that requires no fuselage structure to participate in cargo lifting. Dimensions, weight, and performance data provided by the manufacturer are as follows:

a.	Overall length (rotors included)	88 ft.
b.	Rotor diameter	72 ft.
c.	Wheel tread	19 ft., 9 in.
d.	Overall height (top of tail rotor)	22 ft., 4 in.
e.	Overall height (top of main rotor)	17 ft., 1 in.
f.	Empty weight	19,236 lb.
g.	Normal gross weight	31,000 lb.
h.	Payload (full fuel)	6,000 lb.
i.	Fuel capacity (2000 lb. each engine)	4,000 lb.
j.	Endurance at 31,000 lb. gross ($4\frac{1}{2}$-ton pay load)	30 minutes
k.	Cruising speed	85 knots

IV TESTS

1. General Characteristics.

a. Cockpit Arrangement. The S-60 cockpit design was a new concept with which most helicopter pilots are unfamiliar. The pilot's seat level was approximately four feet lower than the H-37; thus to the pilot, the movement of the aircraft on the roll axis was much more pronounced and created a tendency for the pilot to overcontrol in hovering flight. Cockpit access was afforded by an entrance door from the right

rear of this new style cockpit with two steps to facilitate easy entrance from the ground. Both pilots' seats were comfortable and adjustable in the up and down positions. The pilot on the left was equipped with a swivel seat which enabled him to place himself in the best possible position either to fly forward or to become the crane operator.

By removing the cyclic stick and unlocking the seat and turning the seat 180 degrees, he became the crane operator and had a full view of loading, unloading, tow and all other operations. The cockpit arrangement provided excellent all around visibility. Emergency escape was afforded through both pilots' windows. Ventilation was satisfactory both in flight and on the ground. With the swivel seat facing forward, enough space was provided to the rear of the seat to install one jump seat. Also a jump seat was installed to the rear of the pilot's seat and could be used either as an observer or crew member seat during flight operations. This observer's seat had a limited amount of space.

b. Instruments. The arrangement of instruments on the panel was similar to the H-37 helicopter. The instrument panel location was slightly lower, thus making some of the instruments more difficult to read. With the swivel seat facing to the rear the crane operator was provided with the necessary instruments for hover flight and hoist operations. The instruments provided were:

(1) Manifold pressure
(2) Tachometer
(3) Torque meter
(4) Tensiometer
(5) Winch oil pressure
(6) Attitude indicator
(7) Twist grip indicator
(8) Winch warning lights, which included:
   (a) Cable full in and full out
   (b) Hook automatic release
   (c) Hook unlocked

This instrument arrangement was on a narrow vertical panel in the upper right corner of the cockpit. The selection of instruments for the crane operator was adequate; however, the panel location was unsatisfactory and should be relocated to provide the best line of sight for the crane operator for both hovering flight and for crane operations.

c. Aircraft Controls.

(1) Flight Controls. Flight controls were located within easy reach of both pilots when facing forward. Antitorque pedals were adjustable both fore and aft; brakes were provided on both sets of pedals and the cyclic and collective pitch control were suitably positioned for both pilots' comfort. The collective pitch stick and throttle were attached to and rotated with the swivel seat, thus providing the crane operator with standard controls when facing to the rear. The aft antitorque pedals were adjustable fore and aft; brakes were not provided, or considered to be

necessary. The switches and controls provided on the crane operator's collective pitch stick were:

(a) Cargo hook release
(b) Fast button - to increase winch speed
(c) Search-light control
(d) Hoist up and down
(e) Servo control
(f) Throttle friction
(g) Throttle
(h) Collective pitch friction

The switches and controls provided on the crane operators cyclic stick were:

(a) Cargo hook release
(b) Stick trim
(c) Stick trim - four-way bungee fine trim
(d) ASE release
(e) Radio and intercom

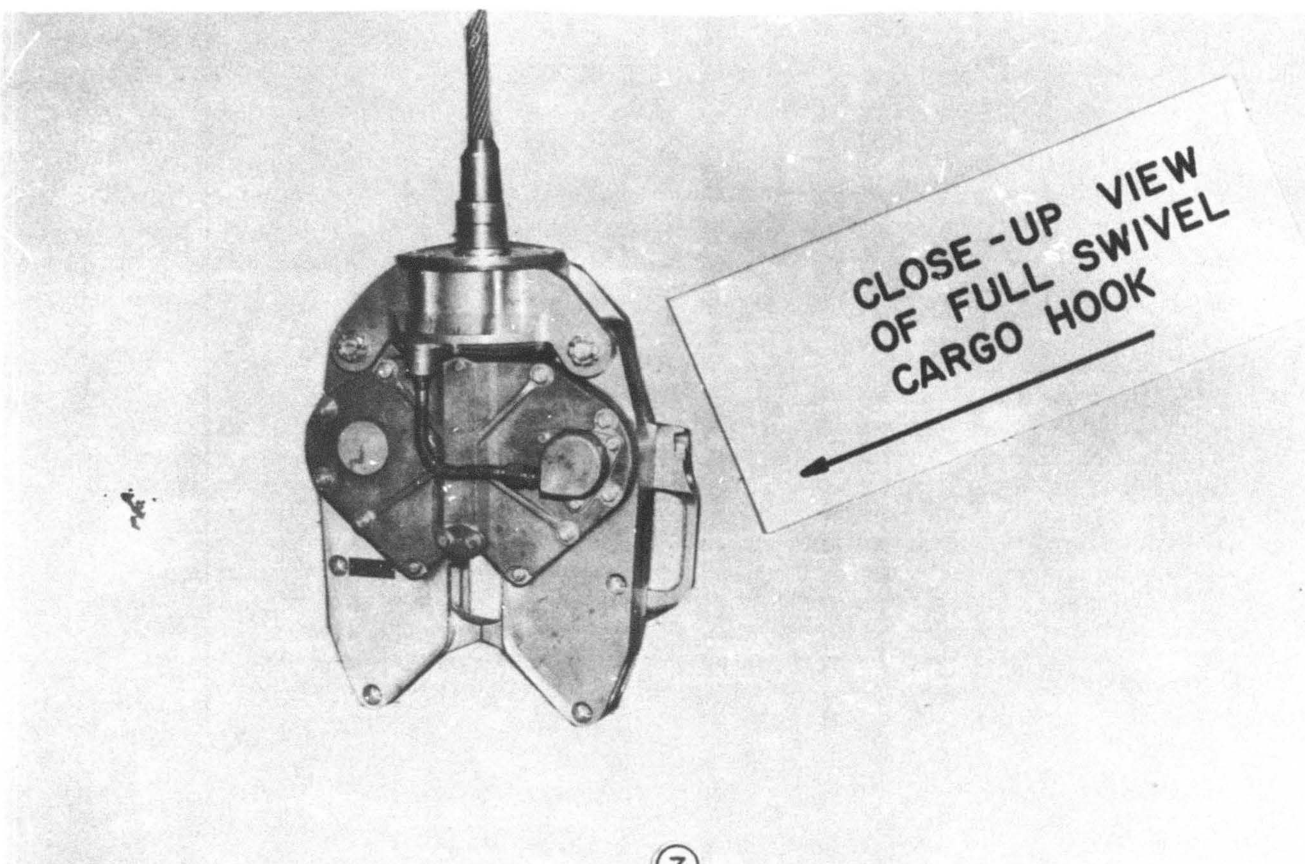
The cargo hook release was duplicated on both the collective and cyclic controls. This is a desirable feature as it allowed flexibility for the crane operator. There were two hoist shear circuits with explosive cutters provided for the crane operator to be used in case of emergency. These switches were located to the right and above the operator. It is felt that if an emergency should arise to the point that either of these switches should be needed, both hands would also be needed on the controls. Otherwise, the above controls provided for the crane operator were considered to be adequate.

(2) Automatic Stabilization Equipment. The ASE installed on the S-60 was manufactured by the Lear Corporation. This equipment controlled pitch, roll, yaw and altitude. The ASE was considered to be a highly desirable feature because this equipment helped to decrease the work load tremendously.

(3) Formation Stick. A formation stick was provided for the crane operator in addition to the standard cyclic stick. This stick was electrically connected to the ASE as a hover coupler and was controlled by the right hand. The formation stick was provided with a four-way (lateral and fore-and-aft) electric trim control. The formation stick was used to control the aircraft when more precise flight tolerances were desired while hovering. The formation stick concept was considered to be a desirable feature; however, in the S-60 it was not working properly at times. The present experimental location of the formation stick was undesirable because it placed the crane operator in an uncomfortable position.

d. Installed Equipment.

(1) Winch and Cargo Hook. The S-60 was equipped with a multipurpose winch and cargo hook which included design features to simplify cargo-handling from the ground and in the air such as:



(a) Cargo Hook Features:

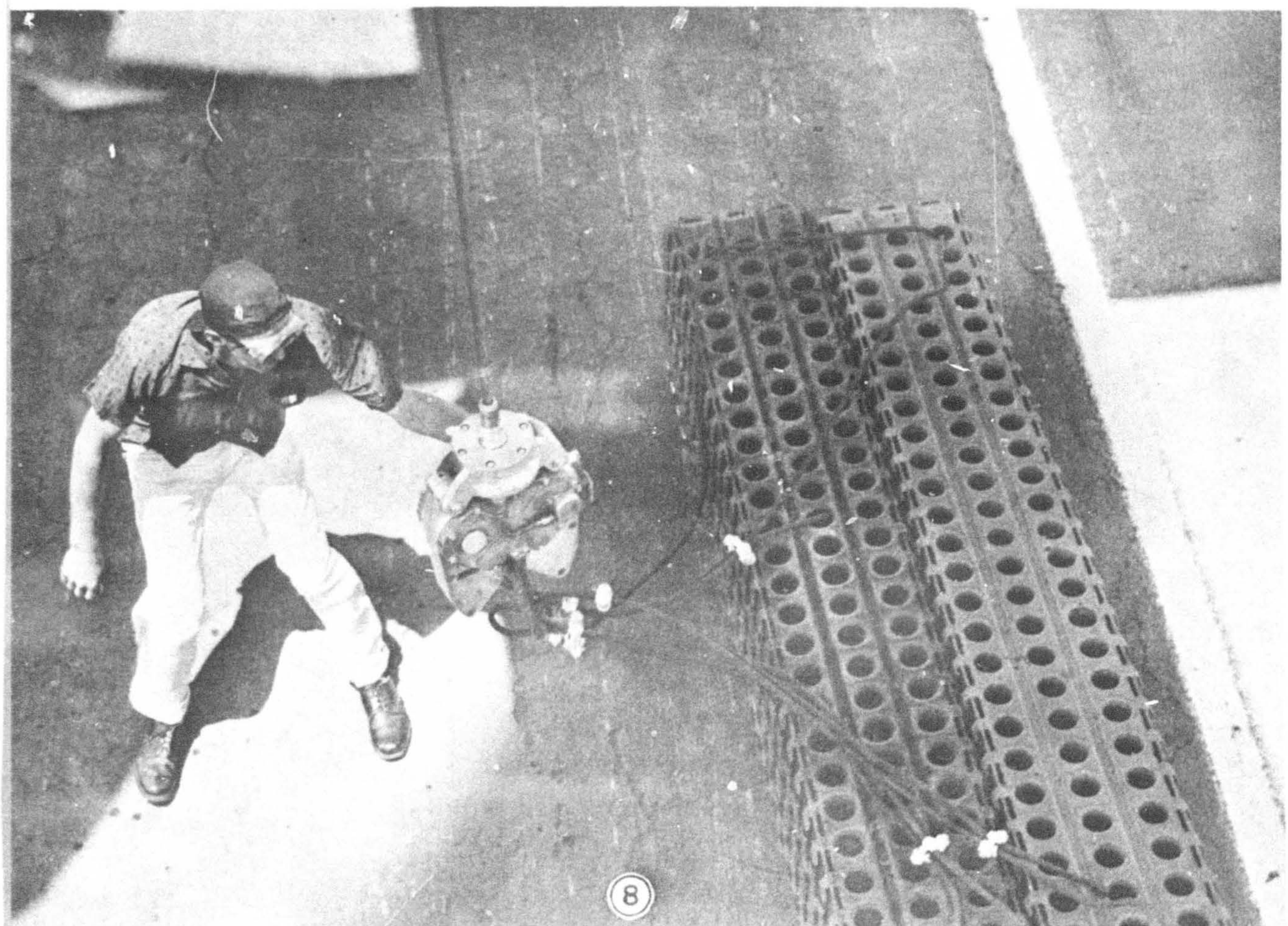
1. Single flexible cable suspension - requires only one ground crewman to position the hook over the load.

2. Spring-loaded hook jaws - allows hookups to be completed in one motion. By grasping the handle with one hand the ground crewman guided the hook over the load and pushed it over the cargo ring for hookup.

3. Multiple release mechanisms - designed to release loads automatically on touch down, from the cockpit or from the cargo hook itself.

4. Water tight.

5. Free swiveling - (360 degrees).



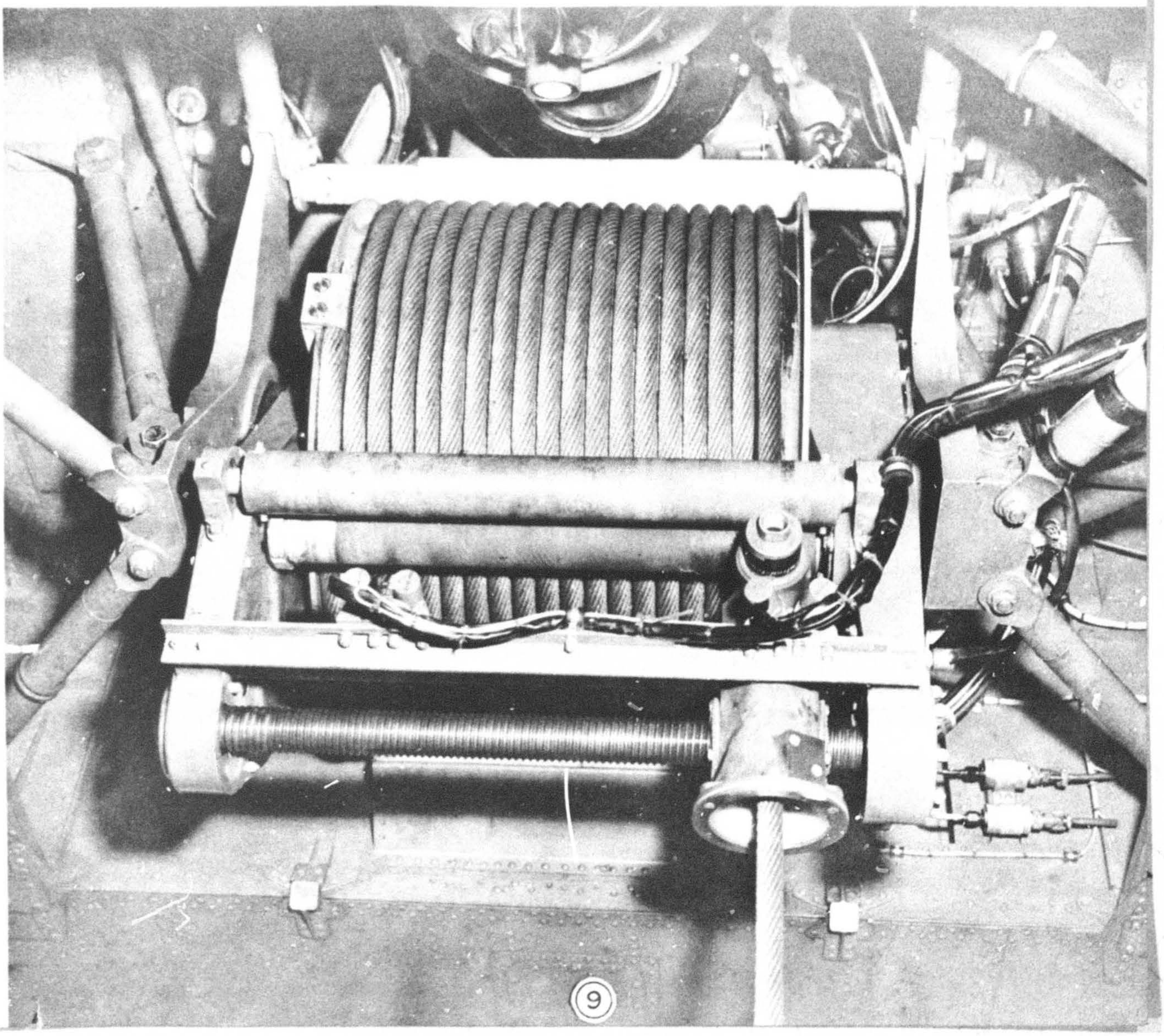
(b) Winch Features:

1. Four speeds - two speeds up and two speeds down, all controlled from the collective stick.

2. 100-foot cable - capable of being paid out to full length or returned with a full load.

3. Cable length indicator - to show the exact amount of footage between the winch and load.

4. Built-in scale (tensiometer) - to indicate the weight of each load.



The complete assembly weighed approximately 1000 pounds and had a 12,000-pound rated capacity. One hundred and twenty feet of one-inch cable was available with 100 feet being usable. The cable was double bound to make it non-twisting, and the electrical wiring to the hook was enclosed in the cable. The hook weighed approximately 70 pounds.

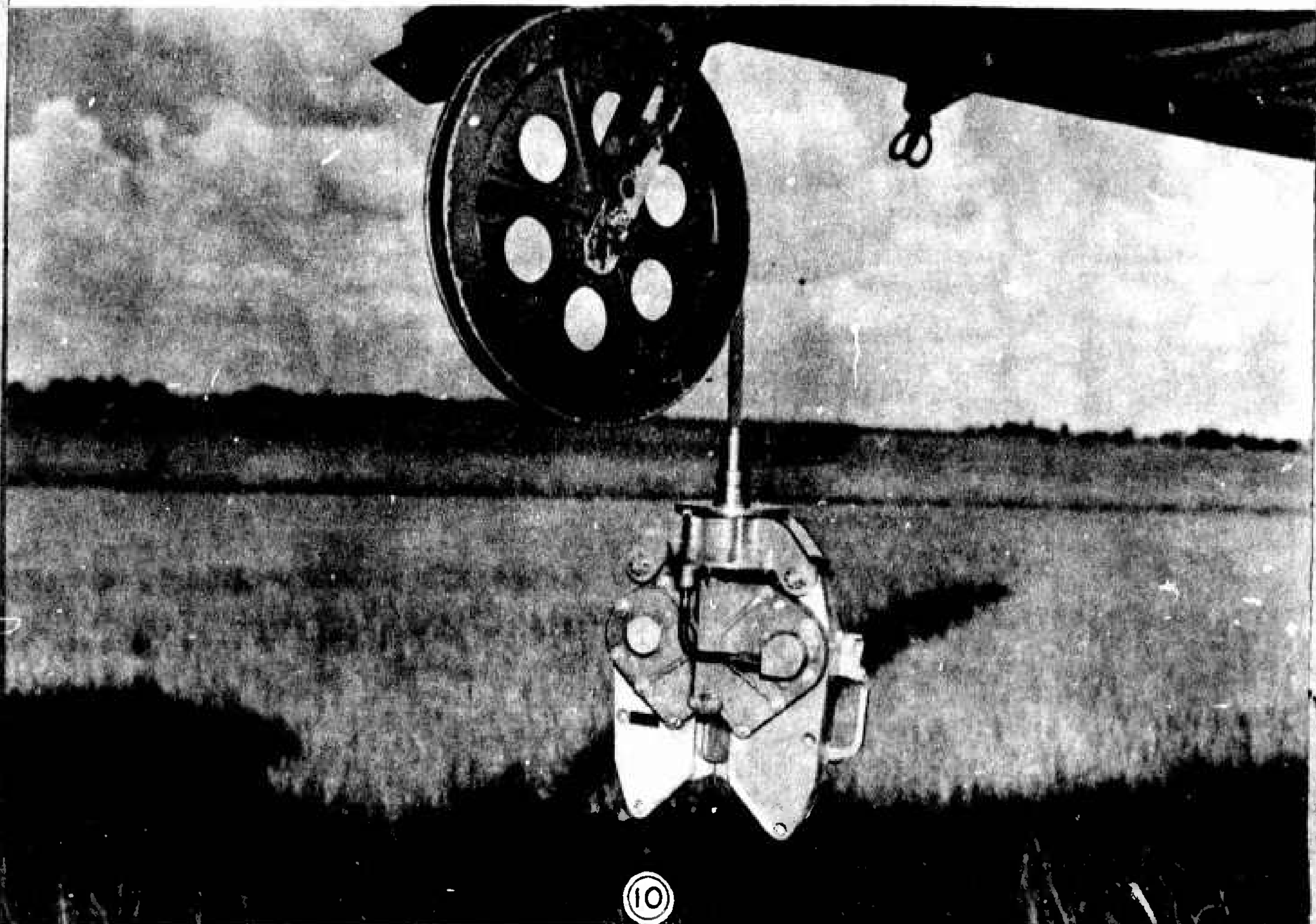
e. Auxiliary Equipment.

(1) Tow Beam and Pulley. For towing, a beam and pulley weighing 125 pounds was attachable to the airframe in approximately 15 minutes. This equipment served two purposes:

(a) To hold the line of pull in line with the center-of-gravity as nearly as possible.

(b) To hold the cable positioned in line with the center of the aircraft.

This equipment could easily be designed into the airframe, thus making it permanent and not auxiliary equipment.



(2) Multipurpose Pods. Two of the pods under future consideration were evaluated. These were the personnel-transport and cargo-transport pods. Both were quick-attachable and-detachable. Neither could be released from the cockpit, but both were releasable by ground crewmen. The pods were attached to the aircraft by cables and hooks which were attached to "O" rings located at "hard points" on the fuselage and were cinched tight by ratchet controls. The "people pod" seated twenty personnel. One end of the cargo pod could be detached from the fuselage, and the aircraft was lifted to a hover to unload the cargo similar to a "dump-bed."

THE PEOPLE POD

Vertical bungees were installed between the pod hookup points and the "O" rings, thus showing possibilities of eliminating vibration in certain types of these pods. The use of pods is feasible, and it is believed consideration should be given to multipurpose pods.

f. Radios. The S-60 was equipped with civilian radios; however, it is important to note that for crane operation it is not only desirable, but necessary, that the pilot and crane operator have intercommunications during all operations. It is desirable that the jump seat provided for an observer also be connected to the intercommunications system.

g. Noise Level. The noise level of the S-60 was similar to the noise level of the H-37 helicopter. It is believed that by use of turbine-engines located properly, the noise level of crane-type aircraft could be reduced considerably.

2. Pilot Transition Training. Basic transition training is essentially the same as required for an H-37A. In addition to these requirements, it is desirable that the pilot, in order to become proficient as a crane operator, spend from 2 to 5 hours in the crane operator's seat to develop his proficiency further. The first portion of this time should be used in learning to control the aircraft while facing to the rear in hovering flight. The next phase of flight should be used to control the aircraft by assistance of the Automatic Stabilization Equipment, and finally controlling the aircraft by use of the formation stick. During these phases of flight, attention should be given to attitude, altitude, direction and movement of the aircraft over precise points. At any time during these phases of training it is desirable for him to become proficient in the use of the hoist switches, their location, and the hoist operation. When he considers himself to be proficient in the crane operator's duties; external hookups, forward flight, approaches and releases may be commenced with both pilots flying as a team. During this time an assortment of loads should be utilized for familiarization with the aircraft flight characteristics and the flight characteristics of different types of loads. It is important to note that the crane operator, when facing to the rear, is not relieved of the copilot's duties in assisting the pilot.

3. Tactical Suitability.

a. Hookup and Release Techniques. Of the hookup techniques that were evaluated while flying the S-60 the following technique was considered to be the most effective. The crane operator's seat and the cyclic stick should be placed in the aft position while the aircraft was

on the ground, thus eliminating accidentally striking the controls. This was also accomplished while hovering or in flight; however, flight safety precautions were taken. The aircraft approach was made directly toward the load by the pilot in the right seat, while in a hover or slow forward flight. This allowed maximum visibility. As the load came into view of the crane operator, he would take the controls and on the intercom state "I have the aircraft." From that time, he was in control of the aircraft and conducted loading operations. From his location, he was in visual contact with the load and ground personnel and had control of the winch and hook. When the hook was engaged and the load was ready for flight, the crane operator then stated "You have the aircraft." At that time, the pilot in the right seat resumed control and proceeded into forward flight. Loads were best released from hovering flight. After the aircraft was brought to a hover, the crane operator would again state "I have the aircraft," stabilize his aircraft, position and release the load. When the aircraft was ready for forward flight the crane operator stated so, passed the control, and was relieved of the pilot's duties. Hookups and releases were made while hovering at altitudes of 3 feet to 75 feet. The higher the hover, the more difficult it was to perform either of these operations. This was attributed to depth perception, hook oscillation, and restricted downward visibility.

(1) Ground Personnel. For the crane concept, only one person was required on the ground. It was desirable that he be equipped with a protective hood or goggles, and gloves to help protect him from blowing debris.

(2) Static Electricity. Static electricity was evident to ground personnel during all hookups. An adequate means of eliminating effects of static electricity before contact is made with any part of the aircraft should be considered.

b. Flight Characteristics of Loads.

(1) The following types of loads were flown with the S-60 helicopter at the stated airspeeds.

(a) One bundle of PSP @ 5040 lb. 70 kts.

(b) One bundle of 4 telegraph poles 35 feet long, 2650 lb. 60 kts.

(c)	One bundle of 5 telegraph poles 20 feet long, 1500 lb.	70 Kts.
(d)	One jeep, 2500 lb.	60 Kts.
(e)	One trailer, 4800 lb.	60 Kts.
(f)	One conveyor, 6940 lb.	50 Kts.

(g) One 105mm howitzer, 4800 lb. — 50 Kts.

(h) One house - 15' x 15' x 12', 7000 lb. — 40 Kts.

(i) One cargo transport pod with drums of water, 2000 lb. — 70 Kts.

(j) One passenger pod with passengers, 4500 lb. — 80 Kts.

(k) Two $\frac{1}{4}$-ton trucks (jeeps) coupled with $\frac{1}{4}$-ton trailer @ 2600 lb. ea. + 550 lb = 5750 lb. — 70 Kts.

(l) One $1\frac{1}{2}$-ton truck with howitzer 7500 lb. — 60 Kts.

(m) One $1\frac{1}{2}$-ton trailer, 1500 lb. — 60 Kts.

(n) One metal pallet with 12 drums of water, 6500 lb. — 70 Kts.

(2) Some of the problems encountered while transporting the above loads were:

(a) The cargo hook did not recess into the fuselage, thus preventing cinching of the loads to the airframe.

(b) Oblong loads had a tendency to rotate and oscillate. To transport loads of this nature safely it was necessary to let the load extend below the landing gear and cockpit.

(c) Loads with large flat plate areas had to be transported at a reduced airspeed.

(d) Greater clearance from the ground to the fuselage was needed when loading bulky loads when not hovering.

(e) Loads suspended from four "hard points" had a tendency to swing fore-and-aft when not cinched snug to the airframe.

(f) The winch oil pump had a tendency to overheat when winding in heavier loads distances of 50 feet and longer, thus making it impossible to reel in using the fast speed.

(g) It is believed that many of these problems could be reduced and possibly eliminated by:

1. Cinching the load to the fuselage.

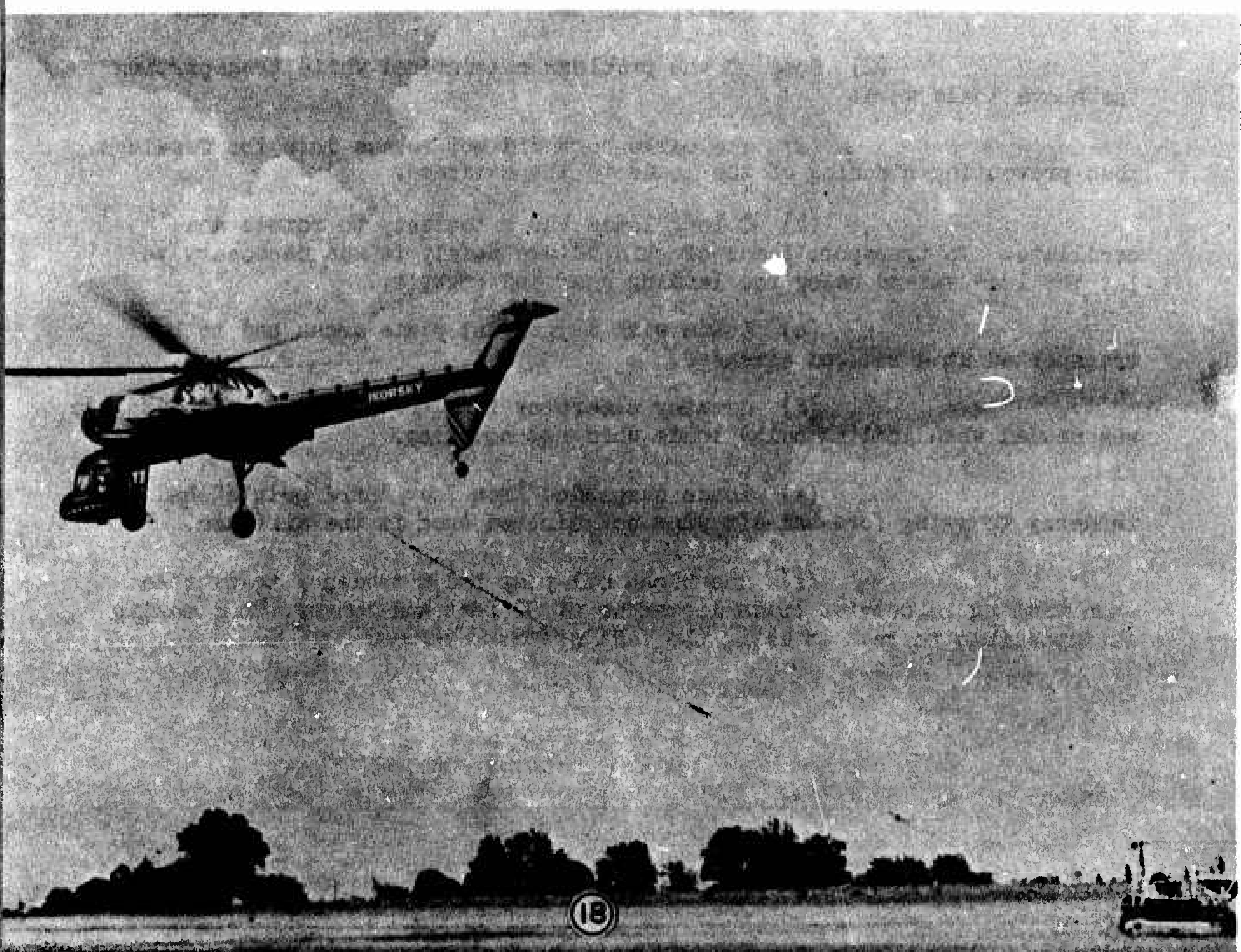
2. Using a retractable tricycle landing gear with a wider tread on the main gear.

3. Raising the cockpit location or moving the cockpit further forward thus allowing more distance for oblong loads.

4. Using, as a last resort, stabilizators on the loads.

5. Using load positioners, sway braces or bumpers.

c. __Towing__. Tow operations with the S-60 were curtailed because of time and nonavailability of heavy equipment. One 16-ton bulldozer and one 10-12 ton crane were towed.



It was estimated that an 8- to 10-degree angle of inclination was used and 15 to 20 knots' forward speed was obtained. The equipment was towed on soft sand and sod. This did not approach maximum tow possibilities by any means for this type of aircraft. A study of tow operations of the HR2S helicopter showed that a 30-degree angle of inclination is possible with cable tensions of 12,000 pounds and better, with no unusual difficulties being encountered. A tricycle landing gear would be most desirable for tow operation, thus eliminating interference of the tail pylon at extremely low altitudes. Consideration should be given to the permanent installation of towing equipment in future cranes.

d. Night Flying. The S-60 was flown at night for evaluation. The aircraft was equipped with a landing light both fore-and-aft, and a flood light aft. There was no reflection or glare in the cockpit from the external lights. The internal lights were of a standard configuration. Hookup and release techniques were the same as daylight operations and no unusual difficulties were encountered. It was desirable to have the ground crewman dressed in light colors or cloth fluorescent strips attached to his clothing.

e. Flight Safety. Because of the requirement to operate for extended periods of time in the "dead man's curve" area, the crane should be designed so that sufficient power is available to make a safe landing in the event of an engine failure.

4. Maintenance. Maintenance requirements were not determined since manufacturer personnel performed all maintenance.

V CONCLUSIONS

1. The configuration of the S-60 is practicable and should be embodied in any future design of rotary-wing heavy lift devices considered for Army use.

2. New developments of the crane concept should take into consideration the deficiencies and the recommended action listed in the appendix.

APPENDIX

	DEFICIENCIES	RECOMMENDED ACTION
1.	The pilot's seat level being below the roll axis of the aircraft resulted in a tendency for the pilot to over control.	Consideration should be given to this deficiency in any future concept.
2.	Space for the observer was limited.	Increase observer's space provided a requirement is established for an observer.
3.	Lower instruments on the forward panel are difficult to read.	Relocate necessary flight instruments.
4.	Rear panel location does not provide best line of sight.	Relocate panel to provide the best line of sight for the crane operator.
5.	Hoist shear circuit toggle switches location requires removal of hands from controls.	Relocate switches so that in case of emergency the crane operator's hands do not have to be removed from the controls to activate the circuit.
6.	The location of the formation stick was awkward. V.1.c.(3)	Relocate the formation stick for a more comfortable position for the crane operator.
7.	Tow operations required installation of auxiliary equipment. V.1.e.(1)	Consideration should be given to this equipment being of a permanent nature on this type aircraft providing a requirement for a tow capability for this type aircraft is established.
8.	Multipurpose pods could not be released from the cockpit in emergency.	Provide emergency cockpit release for all pods except the personnel pod.
9.	The cargo pod could not be released from the cockpit for "dump-bed" type of operations.	Provide cockpit release for the cargo pod for "dump-bed" operations.
10.	Noise level was too high.	Reduce noise level.

	DEFICIENCIES	RECOMMENDED ACTION
11.	Hookup and releases were more difficult at increased hover altitudes.	Eliminate hook oscillation and increase downward visibility.
12.	Static electricity was evident to ground personnel during all hook ups.	Provide some means to eliminate effects of static electricity.
13.	The cargo hook did not recess into the fuselage.	Recess the cargo hook in the fuselage.
14.	Oblong loads had a tendency to rotate and oscillate.	Provide an adequate method of cinching the load to the fuselage and/or sway braces, or provide a retractable landing gear and raise the cockpit level or move the cockpit forward.
15.	Loads with large flat plate areas had to be transported at reduced speeds.	Same as 14.
16.	Loads when suspended from "hard points" had a tendency to swing fore and aft when in forward flight.	Same as 14.
17.	Winch oil pump had a tendency to overheat.	Provide adequate cooling for the winch oil pump.
18.	The tail-wheel pylon interfered with tow operations at low altitudes.	Provide tricycle landing gear.
19.	Available power required extended operation in the "dead man's curve".	Consideration should be given to providing maximum safety for personnel and aircraft during extended flight in the high hovering and low airspeed caution areas. (Eliminate the "dead man's curve".)